*Title:* **Adaptive filtering techniques for land surface data assimilation, Water Resources Research (AGU Journal)**

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*Abstract:*
The accurate specification of modeling and observational error information required by data assimilation algorithms is a major obstacle to the successful application of a land surface data assimilation system. The source and statistical structure of these errors are often unknown and poor assumptions concerning the relative magnitude of modeling and observation uncertainty degrade the quality of land data assimilation products. In theory, adaptive filtering approaches are capable of estimating model and observation error covariance information during the on-line cycling of a data assimilation system. To date, however, these approaches have not been widely applied to land surface models. Here, we implement and compare four separate adaptive filtering schemes in a data assimilation system designed to ingest remotely-sensed surface soil moisture retrievals. Upon testing of each scheme via a synthetic twin data assimilation experiment, three of the four adaptive approaches are found to provide substantially improved soil moisture estimates. However, the specific model and observation characteristics of satellite-based surface soil moisture retrievals contribute to the relatively slow convergence of all schemes. Overall, results highlight the need to consider unique aspects of the land data assimilation problem when designing and/or evaluating the relative performance of adaptive filtering algorithms.


*Popular Summary:*
Satellites are often used to measure properties of the Earth's atmosphere, oceans, or land surface from space. Data assimilation systems are then used to combine such satellite observations with computer models of Earth system processes and to estimate land surface conditions that cannot be observed from space but are needed for applications. For example, moisture in the top few centimeters of the soil can be observed from satellite, but not soil moisture in the top meter of the soil. The latter is needed for drought assessment and forecasting. Good data assimilation results rely on accurately understanding the errors in the satellite observations and in the Earth system model. These errors, however, are very difficult to characterize because accurate ground-based observations are typically lacking. In this paper we investigate four different adaptive data assimilation methods that estimate not only the land surface properties (such as soil moisture) but also the errors in the satellite observations and in the Earth system model. We demonstrate that three of the four methods provide improved soil moisture estimates when compared to non-adaptive estimation. However, the specific characteristics of satellite-based surface soil moisture estimates and land surface processes pose unique challenges. In particular, multi-year observing periods are required for the optimal estimation of the desired error characteristics. Our results highlight the need to consider unique aspects of the land data assimilation problem when designing and/or evaluating the relative performance of adaptive data assimilation methods.